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Recent Advances in the Oral Therapeutic Applications of Salvadora persica (Miswak): A Comprehensive Review

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ABSTRACT

Oral diseases affect more than three billion people globally, with dental caries and periodontal disease representing the largest share of the burden. Despite widespread use of fluoride products and chlorhexidine-based antiseptics, conventional oral hygiene tools carry persistent limitations, including adverse effects, access barriers in low-resource settings, and concerns about long-term microbiota disruption. *Salvadora persica*, the source of the traditional miswak chewing stick, is a WHO-endorsed oral hygiene tool with deep cultural roots across the Middle East, Africa, and South Asia. This narrative review synthesises evidence published between 2021 and 2025 on its phytochemistry, mechanisms of oral therapeutic action, clinical efficacy across oral conditions, comparative performance against conventional agents, novel formulations, and safety profile.

Benzyl isothiocyanate, derived from glucosinolates concentrated in *S. persica* roots, acts as the primary antimicrobial constituent through membrane disruption and biofilm inhibition against

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Streptococcus mutans, *Porphyromonas gingivalis*, and *Fusobacterium nucleatum*. Flavonoid polyphenols modulate COX-2, TNF-alpha, and IL-6 pathways, while mineral constituents support enamel remineralisation through calcium, phosphorus, and fluoride ion release. Meta-analyses and randomised controlled trials confirm that miswak in stick, toothpaste, and mouthwash forms reduces plaque and gingival inflammation comparably to conventional toothbrushing, with adjunctive use producing significantly greater reductions than mechanical cleaning alone. Performance against chlorhexidine is somewhat lower for plaque control but comparable for soft tissue anti-inflammatory outcomes. Preclinical models support wound healing and early antiproliferative activity, while nanoparticle-based formulations show enhanced antimicrobial potency. Evidence gaps remain in long-term safety, paediatric populations, and microbiome-level outcomes

Keywords: *Salvadora persica,* Miswak, Benzyl isothiocyanate, Periodontal disease, Oral hygiene

Introduction

Oral diseases affect more people than almost any other non-communicable condition. A 2025 Lancet analysis reported that the global burden of oral conditions exceeded 3.5 billion cases in 2021, with untreated dental caries in permanent teeth and severe periodontitis carrying the largest burden [1]. Projections drawn from Global Burden of Disease 2021 data indicate that both conditions will continue rising through 2035, with the steepest increases expected in low- and middle-income regions [2].

Modern oral hygiene tools work reasonably well under the right conditions. The problem is that those conditions do not apply to most of the world. Chlorhexidine gluconate, the most prescribed antiseptic rinse in dentistry, produces tooth staining, mucosal irritation, and taste disturbance with prolonged use [3]. Mouthwashes with broad-spectrum antimicrobial activity also raise concerns about oral microbiota disruption and potential resistance development over long-term use [4]. In low-resource settings, cost and supply of commercial dental products remain genuine barriers to consistent oral hygiene practice [1,2]. These are not marginal problems. They affect access to care for a substantial portion of the global population.

This creates a practical gap. A tool that controls plaque and reduces gingival inflammation without depending on a pharmacy supply chain and without carrying a profile of adverse effects that limits its use would be clinically and publicly useful. Salvadora persica, the plant source of the miswak chewing stick, has filled that role in many regions for centuries. Whether current evidence supports a more formal and systematic role for it in oral health care is the question this review examines.

1.1 Historical, Cultural, and WHO-Endorsed Significance of Miswak

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Salvadora persica is a small tree native to arid zones across Africa, the Arabian Peninsula, and the Indian subcontinent. Its roots and stems have been used for oral hygiene for over a thousand years, with documented practice across Islamic, African, and South Asian traditions predating modern dentistry [5,6]. The use of miswak is recommended in Islamic religious texts and continues to be culturally embedded in communities across the Middle East, parts of sub-Saharan Africa, and South Asia, often alongside rather than instead of commercial toothbrushes [7,8].

The World Health Organization has formally recommended miswak as an effective oral hygiene tool in communities where its use is established [5]. Systematic reviews and randomised trials have found that both the chewing stick and S. persica extract mouthwashes can reduce plaque accumulation and gingival inflammation to a degree comparable with standard toothbrushing and chlorhexidine rinsing over short follow-up periods [6,8,7]. The stick also biodegrades, requires no packaging, and is available at low cost in regions where the tree grows naturally [5].

The evidence is not without complications, however. Technique is a critical variable, and irregular or vigorous use has been linked to gingival recession and cervical tooth wear in some user groups [9]. Studies also differ substantially in how miswak use is defined and measured, which complicates cross-trial comparisons.

1.2 Objectives of This Review

Research on miswak has grown considerably in recent years. Extract-based toothpastes, mouthwashes, and nanoformulations have been tested in clinical and laboratory settings, and meta-analyses have begun pooling data from randomised controlled trials [6,8,7]. Despite this output, the evidence base remains fragmented. Study designs, miswak sources, preparation methods, and choice of outcome measures vary widely, and few trials follow participants beyond three months [6].

This review synthesises evidence from 2021 to 2025 on the oral therapeutic applications of S. persica. It covers phytochemistry and mechanisms of action, clinical outcomes across oral conditions, performance relative to conventional agents, novel formulations, and safety profiles. It also maps where evidence is insufficient and where research effort is most needed.

2.0 Botanical Profile, Ethnobotany, and Phytochemistry of Salvadora persica

2.1 Taxonomy, Morphology, Distribution, and Plant Parts Used

Salvadora persica L. belongs to the family Salvadoraceae and grows as a perennial shrub or small tree in arid and semi-arid zones [5]. It is known regionally by several names, including 'arak' and 'peelu', and in dental literature almost universally as the toothbrush tree [5,13]. Natural populations are distributed across the Arabian Peninsula, North and East Africa, South Asia, and

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coastal areas of the UAE, typically in sandy soils, dune systems, and wadi margins [5,13]. Overcollection for oral hygiene use has placed the species under threat in parts of the Arabian Peninsula [10].

The roots and twigs are the main plant parts used in oral hygiene practice. Short lengths of root or stem are cut, the bark at one end is softened by chewing or soaking, and the exposed fibrous tip is pressed against tooth surfaces to remove plaque [5,18]. In some traditions, leaves are prepared as mouthwash decoctions or applied directly for gum complaints [10]. Fruits and aerial parts have received research attention for their phenolic and antioxidant properties, though their direct clinical use in oral care is less established [14].

Physical properties of the stem are relevant to its function. The wood resists fracture under normal chewing force, and the fibrous tissue released at the working end forms an effective mechanical cleaning surface [18]. Environmental variables including soil moisture, temperature, precipitation, and pH measurably alter functional traits such as tree height, leaf size, and biomass allocation in S. persica populations [16], suggesting that growing conditions influence the plant's structural characteristics alongside its chemistry.

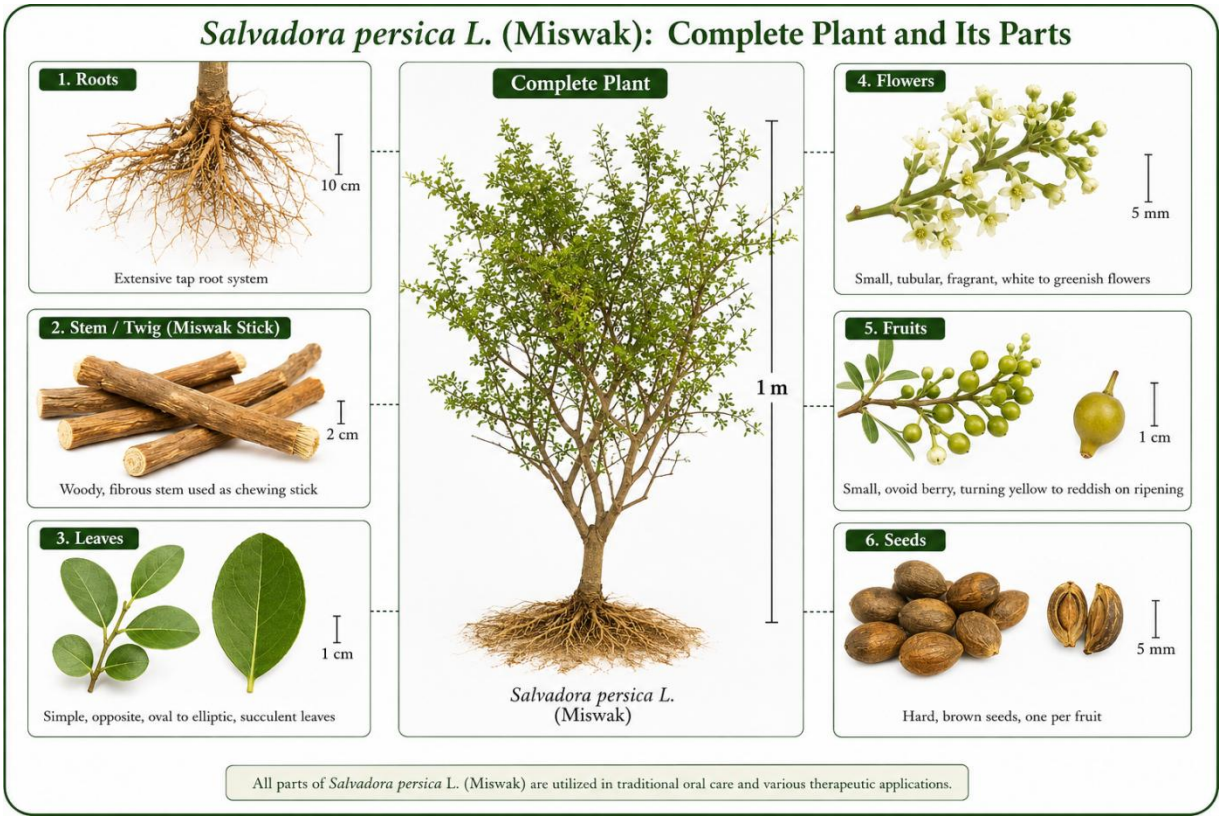

Figure 1. Representative morphology of Salvadora persica (Miswak)

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2.2 Traditional Use Across Islamic, African, and South Asian Ethnodentistry

The use of S. persica chewing sticks for oral hygiene is documented in Islamic religious texts and has been practised across the Middle East for centuries [18]. The habit is embedded in daily routines across the Arabian Peninsula, sub-Saharan Africa, and Muslim communities in South Asia and persists in urban populations with access to commercial dental products [19]. The World Health Organization formally recommended S. persica chewing sticks as an effective and cost-appropriate oral hygiene tool in communities where their use is customary [18].

Ethnopharmacological documentation from the UAE records S. persica roots, twigs, and stems as recognised tools for antiplaque, anticaries, anti-inflammatory, and antifungal effects within traditional Arabic medicine [5,13]. Surveys across the Arabian Peninsula also document broader medicinal applications covering infections, fevers, and gastrointestinal conditions, with oral hygiene remaining the most consistently cited use [13].

In Africa, S. persica is used both as a chewing stick and as a remedy for inflammatory and febrile conditions, with documented practice in Chad and East African communities [15]. Chemical analysis of Chadian samples returned notably low phenolic and antioxidant values compared with other co-collected medicinal plants, which raises questions about regional chemotype variation or differences in collection and extraction methods [15].

In South Asia, leaves and twigs are prepared as mouthwash decoctions or used in direct contact with tooth surfaces for strengthening and cleaning [10]. The broader tradition of chewing stick use across human cultures predates Islamic practice, with historical documentation from ancient Egyptian, Babylonian, and Greek civilisations [18].

2.3 Key Bioactive Phytochemicals and Their Oral Health Relevance

S. persica contains a range of secondary metabolites distributed across its plant parts. Documented compound classes include flavonoids, glycosides, sterols, terpenes, alkaloids, organic sulphur compounds, and elemental sulphur [5]. Among these, the glucosinolate-derived isothiocyanates carry the most direct evidence for oral antimicrobial activity.

Benzyl isothiocyanate (BITC) is the primary antimicrobial component. It is produced from glucotropaeolin, a benzyl glucosinolate found in leaves and roots, through enzymatic hydrolysis activated during chewing or extract preparation [5,10]. Gas chromatography-mass spectrometry analysis of petroleum ether root extracts identified BITC at approximately 36% of the volatile profile; the same extracts showed strong inhibitory activity against beta-lactam-resistant oral streptococcal strains and disrupted biofilm formation [11]. Leaf-based assays found that both glucotropaeolin and BITC suppressed IL-8 and TNF-alpha release from stimulated cells and that

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BITC had antiproliferative activity in vitro, suggesting a role in controlling periodontal tissue inflammation beyond simple bacterial killing [10].

The flavonoid profile of S. persica leaves has been characterised with considerable detail. Identified compounds include isoquercitrin, kaempferol-3-neohesperidoside, myricetin-3-galactoside, apigenin-O-hexoside, isorhamnetin, and isorhamnetin-3-neohesperidoside, alongside phenolic acids including gallic acid [10]. Flavonoid-rich fractions from young leaves produced strong DPPH and ABTS radical scavenging activity and reduced intracellular reactive oxygen species in cell-based models [12]. Fruits and aerial parts separately yielded gallic acid, hydroxybenzoic acid, chlorogenic acid, catechin, rutin, and myricetin, all with measurable antioxidant and anti-inflammatory activity in vitro [14].

Alkaloids in S. persica include salvadoricine, an indole alkaloid identified in leaf metabolite profiling [10]. Trimethylamine and salvadorine appear in older compositional literature but have not been specifically tested for oral bioactivity in recent studies [5]. Minerals including fluoride, calcium, silica, and potassium are cited consistently in ethnopharmacological overviews and are considered contributors to enamel remineralisation and mechanical cleaning during stick use [5]. Saponins are reported in phytochemical surveys and may account for the mild foaming observed when miswak is used [5].

2.4 Phytochemical Variation by Plant Part, Geography, and Season

The chemical profile of S. persica shifts considerably depending on which part of the plant is collected and where it was grown. Young leaves carry higher total phenolic and flavonoid concentrations and stronger antioxidant activity than mature leaves from the same plant [12]. Roots are dominated by sulphur compounds with BITC as the primary quantifiable marker, while leaves hold richer flavonoid and glucosinolate content [5,10,11]. Fruits from Pakistani collections showed higher phenolic and flavonoid levels and stronger antioxidant and anti-inflammatory activity than aerial parts from the same source [14].

Geographic origin is a substantial variable. Samples collected in Chad showed very low total phenolic, flavonoid, and tannin contents with no detectable antioxidant phenolics by HPLC-ABTS analysis, in contrast to Arabian Peninsula and South Asian collections that consistently show richer profiles [15]. Population-level studies in semi-arid Pakistan found that temperature, soil pH, soil texture, and moisture gradients significantly altered S. persica functional traits across sites [16], with secondary metabolite allocation expected to follow similar patterns. Seasonal phytochemical data specific to S. persica are limited in the current literature, though seasonal salinity and heavy metal exposure have been shown to alter water relations and metal accumulation in the species [17], which points to a need for harvest-time standardisation in product development.

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These differences are not trivial for clinical application. An extract prepared from mature roots collected in one region will not have the same BITC or flavonoid content as one prepared from young leaves in another. Any standardisation effort for miswak-based oral care products needs to specify plant part, origin, and ideally the collection period.

Table 1. Phytochemical composition of Salvadora persica by plant part and key oral health relevance

Plant part	Compound class	Key identified compounds	Oral health relevance	Ref
Roots	Glucosinolates / Isothiocyanates	Benzyl isothiocyanate (BITC)	Primary antimicrobial; antibiofilm; membrane disruption in S. mutans, P. gingivalis, F. nucleatum	[5,11]
Roots	Minerals	Fluoride, calcium, phosphorus, silica	Enamel remineralisation; mechanical plaque removal	[5,22]
Roots	Anionic ions	Chloride, sulfur, cyanide compounds	Bacterial cell wall disruption; suppression of genotoxic microbial metabolites	[5]
Young leaves	Flavonoid glycosides	Isoquercitrin, kaempferol-3-neohesperidoside, myricetin-3-galactoside, apigenin-O-hexoside, isorhamnetin	Antioxidant; ROS scavenging; anti-inflammatory via IL-8 and TNF-alpha suppression	[10,12]
Young leaves	Phenolic acids	Gallic acid	Antioxidant; antimicrobial	[10]
Young leaves	Glucosinolates	Glucotropaeolin	BITC precursor; antiproliferative; IL-8 and TNF-alpha inhibition	[10]
Young leaves	Alkaloids	Salvadoricine	Antimicrobial and possible analgesic contribution	[10]
Young leaves	Volatile oils	Essential oil constituents	Antimicrobial; flavouring in oral care products	[5]
Mature leaves	Flavonoids and phenolics	Similar classes to young leaves; lower density	Antioxidant; anti-inflammatory; lower activity than young leaf fractions	[12]
Fruits	Phenolic acids	Gallic acid, hydroxybenzoic acid, chlorogenic acid, cinnamic acid	Antioxidant; anti-inflammatory	[14]
Fruits	Flavonoids	Catechin, rutin,	Antioxidant; anti-inflammatory;	[14]

		myricetin	higher TPC and TFC than aerial parts	
Aerial parts	Phenolics and flavonoids	Similar classes to fruits; lower concentrations	Antioxidant activity; lower than fruit fractions	[14]
All parts	Saponins	Not individually characterised in recent literature	Mild foaming and cleansing during stick use; antimicrobial contribution	[5]
All parts	Sterols and terpenes	Beta-sitosterol and related compounds	Bacterial cell wall disruption; anti-inflammatory	[5,22]

TPC: total phenolic content; TFC: total flavonoid content; ROS: reactive oxygen species

3.0 Mechanisms of Oral Therapeutic Action

3.1 Antimicrobial and Antibiofilm Activity

The antimicrobial action of S. persica is not a product of any single compound working in isolation. Several constituents act together, though benzyl isothiocyanate carries the strongest and most consistently documented activity across bacterial species relevant to oral disease [20].

BITC reaches bacterial cells by disrupting their outer membrane, creating structural protrusions visible under electron microscopy that allow further bioactive constituents to penetrate and interfere with redox systems and membrane potential [20]. Against Fusobacterium nucleatum, a pathogen implicated in periodontitis and colorectal disease, BITC demonstrated a minimum inhibitory concentration of 0.2% and a minimum bactericidal concentration of 0.4% in vitro, eliminating planktonic cells within 24 hours and dismantling established biofilms within 48 hours. The mechanism involved a measurable increase in intracellular reactive oxygen species within F. nucleatum cells, pointing to oxidative stress as a secondary killing pathway alongside membrane disruption and impaired bacterial adhesion [21].

Activity against Streptococcus mutans follows a similar pattern. BITC and other S. persica constituents inhibit glucosyltransferase activity, which S. mutans depends on to build the extracellular polysaccharide matrix of dental plaque. Reduced acid production and plaque formation have been demonstrated in both clinical and laboratory settings [7,20]. Against periodontopathogens, including Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans, chewing stick use produces anti-plaque effects through combined pharmacological inhibition and the mechanical disruption of early biofilm colonisers [7].

Beyond BITC, other constituents contribute to the antimicrobial picture. Beta-sitosterol and anionic ions, including chloride, fluoride, sulphur, and cyanide compounds, can damage bacterial cell walls and suppress genotoxic microbial metabolites on tooth surfaces [22]. A systematic review of antibiofilm evidence confirmed that miswak reduces dental plaque in vivo at levels

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comparable to conventional measures, attributing this to the combined pharmacological and physical action of stick use [18].

3.2 Anti-inflammatory and Antioxidant Pathways

S. persica exerts measurable effects on inflammatory signalling pathways at concentrations relevant to oral use. At the cellular level, S. persica extracts suppress a range of pro-inflammatory cytokines, including IL-1β, IL-6, IL-8, TNF-alpha, and IFN-gamma, and modulate nitric oxide synthase isoform expression [20]. The mechanism proposed for this activity involves inhibition of both cyclo-oxygenase and lipoxygenase pathways, which would reduce prostaglandin, thromboxane, and leukotriene production in inflamed periodontal tissues [20].

Leaf-based experiments provide more targeted evidence. Glucotropaeolin and BITC from S. persica leaves significantly reduced IL-8 and TNF-alpha release from stimulated neutrophils, and BITC showed antiproliferative activity against oral carcinoma cells in vitro [10]. This combination of cytokine suppression and antiproliferative activity is particularly relevant to chronic periodontal inflammation, where sustained neutrophil activity and tissue remodelling contribute to attachment loss.

Antioxidant activity has been tested in an animal wound healing model. A muco-adhesive ethyl acetate fraction of S. persica applied to acetic acid-induced oral ulcers in rats reduced IL-6 and TNF-alpha expression, prevented accumulation of malondialdehyde, and preserved glutathione and superoxide dismutase activity [23]. These findings indicate that S. persica extract can support intracellular redox balance in injured oral tissue rather than simply scavenging extracellular free radicals. Collagen I expression and angiogenesis were also enhanced in treated ulcers, connecting the antioxidant and anti-inflammatory effects directly to tissue repair outcomes [23].

A rat model examining systemic effects of aqueous S. persica extract found reduced serum IL-1β, IL-6, TNF-alpha, and NF-κB alongside restored antioxidant enzyme activity and normalised AMPK/NF-κB signalling [24]. While this was an extra-oral toxicity study, it supports the consistency of NF-κB-mediated anti-inflammatory action across tissue types, reinforcing the plausibility of similar effects in gingival and periodontal tissue.

3.3 Remineralisation, Enamel Protection, and Mechanical Debridement

S. persica contributes to caries prevention through both chemical remineralisation and physical plaque removal. In an ex vivo study comparing S. persica extract with probiotic yoghurt on artificially demineralised enamel, miswak-treated specimens recovered calcium and phosphorus content to levels approaching sound enamel by energy dispersive X-ray analysis, with improved surface morphology under scanning electron and polarised light microscopy [22]. Aqueous extracts released higher concentrations of calcium, phosphorus, and fluoride ions than alcoholic

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preparations, and this ion availability is considered the primary driver of remineralisation activity [22].

S. persica also buffers the acidic conditions that favour caries progression. Its constituents, particularly thiocyanate, enhance the salivary hydrogen peroxide-peroxidase-thiocyanate antimicrobial system and raise plaque pH following sucrose exposure, reducing the window during which S. mutans can demineralise enamel [22]. Silica contributes mild mechanical polishing of the enamel surface alongside pH buffering [10].

The fibrous tips of the miswak stick function as a natural toothbrush. Randomised controlled trials and meta-analyses consistently show that correct miswak use reduces plaque index and gingival index scores to levels equivalent to conventional toothbrushing [6,7,25,26]. This outcome reflects both the physical removal of biofilm by stick fibres and the simultaneous delivery of BITC, tannins, and other actives to the gingival margin during use [18].

Taken together, the antimicrobial, anti-inflammatory, antioxidant, remineralising, and mechanical properties of S. persica are not independent effects. They operate concurrently during normal use, which helps explain why clinical studies repeatedly find outcomes comparable to agents specifically engineered for single-mechanism action.

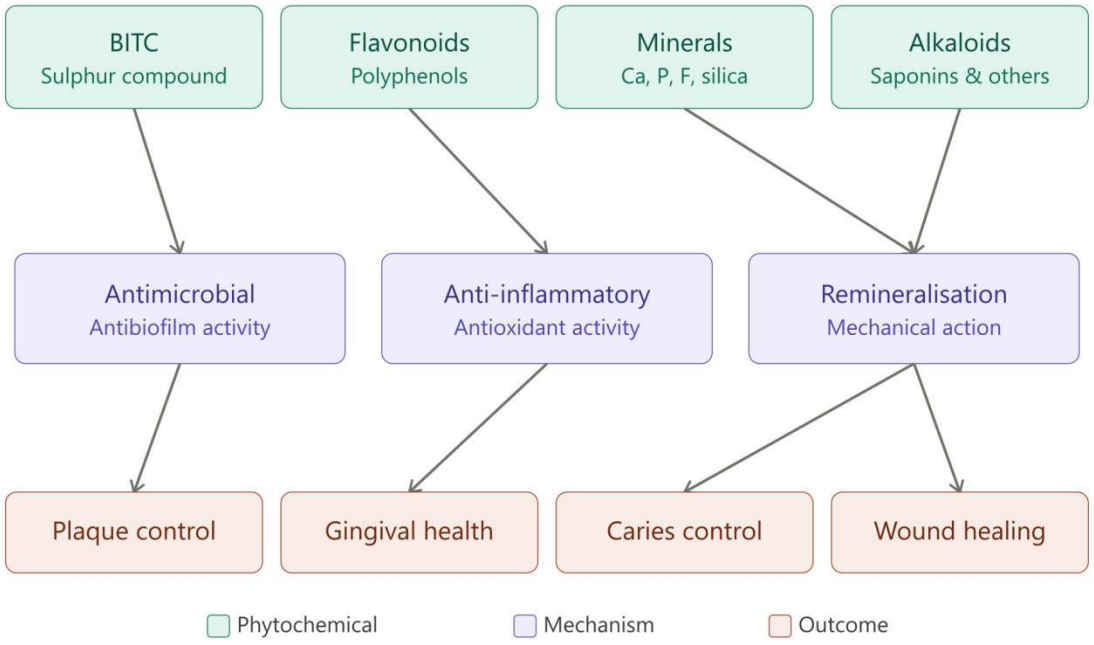

Figure 2. Schematic overview of the oral therapeutic mechanisms of Salvadora persica

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4.0 Clinical Evidence Across Oral Conditions

4.1 Dental Caries Prevention

The caries-preventive case for S. persica rests on two distinct lines of evidence: antibacterial activity against cariogenic organisms and remineralising capacity at the enamel surface. Both have been tested, and they produce somewhat different conclusions.

On the antibacterial side, a three-month RCT in high-caries-risk adults compared a miswak-based herbal toothpaste against a conventional fluoride paste for reduction in salivary S. mutans counts [27]. Both pastes produced significant time-dependent reductions with no statistically significant difference between groups, which suggests that miswak's antibacterial action against S. mutans is clinically meaningful. The fluoride paste, however, released greater concentrations of calcium, phosphorus, silicon, and fluoride ions, indicating superior remineralising ion delivery. The miswak paste appeared to operate primarily through antibacterial inhibition of S. mutans rather than through direct enamel remineralisation [27]. A systematic review covering miswak in stick, toothpaste, and mouthwash forms reached a broadly consistent conclusion: miswak's anticaries contribution works mainly through biofilm control and reduction in cariogenic bacterial load [18].

The remineralisation picture is more promising in ex vivo work. S. persica extract applied to artificially demineralised premolars restored calcium and phosphorus content to levels approaching sound enamel, outperforming probiotic yoghurt as a comparator [22]. Energy dispersive X-ray and polarised light microscopy confirmed surface recovery in treated specimens. One in vitro paediatric study tested a polyherbal gel containing S. persica alongside Zingiber officinale and Cinnamomum zeylanicum against acidulated phosphate fluoride gel, finding better antibacterial and remineralising performance with the herbal preparation [28]. The individual contribution of S. persica cannot be separated from the other components in that formulation, so this result is noted here for context only.

The current evidence supports an anticaries role for S. persica that is primarily antibacterial, with ex vivo remineralisation data that justify controlled clinical testing but do not yet confirm equivalent ion delivery to fluoride-based products.

4.2 Periodontal Disease and Gingivitis

This is where the clinical evidence is most developed. Multiple RCTs and meta-analyses have examined miswak chewing sticks, S. persica toothbrushes, toothpastes, and mouthwashes against various comparators, and the body of evidence is now substantial enough to draw reasonably reliable conclusions.

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Two independent meta-analyses focused on the chewing stick. One, pooling five RCTs, found that S. persica chewing sticks produced plaque reductions comparable to standard toothbrushes and superior gingival index outcomes overall [25]. The other, drawing from ten RCTs on miswak practices more broadly, found that miswak used alone was equivalent to conventional toothbrushing for mean plaque and gingivitis scores, but that adjunctive miswak use alongside toothbrushing produced significantly better plaque and gingivitis outcomes than toothbrushing alone [6]. That adjunctive effect is clinically meaningful. It points to S. persica adding pharmacological benefit beyond what mechanical cleaning achieves by itself.

A three-arm RCT with 78 participants compared S. persica chewing sticks, S. persica-bristled toothbrushes, and standard toothbrushes over three weeks [7]. All three arms showed significant reductions in plaque and gingivitis from baseline. The chewing stick produced the greatest improvement in anterior gingival inflammation as measured by the periodontal inflamed surface area index, though overall plaque and gingivitis outcomes were equivalent across groups when technique was standardised. Technique is a critical variable here. A separate two-week RCT found miswak controlled plaque adequately but produced higher gingival scores than toothbrushing, with the authors attributing this to aggressive use by participants who had not received adequate training [26]. Poor technique, not the plant itself, appears to drive adverse gingival outcomes in most reported cases.

For product-based delivery, a meta-analysis of seven RCTs on S. persica toothpastes found similar anti-plaque and anti-gingivitis effects compared with non-herbal toothpastes [29]. A meta-analysis of sixteen RCTs on S. persica mouthwash versus chlorhexidine gluconate found significant reductions in plaque and gingival inflammation with the miswak rinse, though performance was generally somewhat below chlorhexidine [8]. The authors noted that miswak rinses may serve as an acceptable alternative for patients who experience chlorhexidine side effects or prefer natural products for long-term use. A broader review across multiple S. persica delivery forms, including periodontal films and dentifrices, concluded that adjunctive use consistently improves gingival inflammation and plaque scores beyond mechanical cleaning alone, with select trials reporting outcomes comparable to chlorhexidine [20].

4.3 Halitosis Management

No primary clinical trial in the available literature directly measured volatile sulphur compound concentrations or organoleptic scores for oral malodour with S. persica as the test agent. Any halitosis benefit attributed to miswak in this review is inferred from its documented antibacterial activity against anaerobes that produce volatile sulphur compounds, including the periodontal pathogens addressed in Section 3 [18,20]. That inference is biologically plausible but remains indirect. A targeted halitosis trial with appropriate outcome measures is an identifiable gap in the evidence base.

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4.4 Oral Candidiasis and Fungal Infections

Clinical trial data on oral candidiasis are absent from the current evidence set. Pharmacological reviews of S. persica list antifungal activity among its documented properties, and leaf-based extracts have been used to produce silver nanoparticles with in vitro antifungal activity [5]. These data suggest a biological rationale for further investigation but do not support any clinical conclusion about candidiasis outcomes at this stage.

4.5 Oral Mucositis, Wound Healing, and Antiproliferative Activity

Animal models provide the most detailed evidence for wound healing. In one in vivo rat study, extraction sockets and tongue incisions were irrigated with miswak extract at concentrations ranging from 0.05% to 20% over seven days [30]. The 20% extract produced the highest proportion of healed oral mucosa and the greatest early bone deposition at extraction sites, with no tissue toxicity at any tested concentration. The dose-dependent response across both soft tissue and hard tissue healing endpoints is worth noting because it suggests S. persica supports post-extraction bone repair as well as mucosal closure [30].

A second animal study used a muco-adhesive ethyl acetate fraction of S. persica applied topically to acetic acid-induced tongue ulcers in rats [23]. Treated animals showed accelerated histological healing, higher collagen and hydroxyproline levels, improved angiogenesis, and reduced IL-6, TNF-alpha, and oxidative stress markers relative to both negative and positive controls. This connects the anti-inflammatory mechanism described in Section 3 directly to a measurable tissue repair outcome in an oral wound model [23].

For antiproliferative activity, leaf extracts and isolated constituents were tested against HNO97 human tongue carcinoma cells in vitro [10]. BITC showed an IC50 of approximately 10 μM against these cells and strongly suppressed IL-8 and TNF-alpha release. Selected flavonoids and a megastigmane sulphonoglycoside from the leaf showed moderate antiproliferative activity in the same model [10]. These are cell line findings, and the gap between an in vitro IC50 and a clinical application is substantial. The specificity of BITC against a tongue carcinoma line, combined with its established anti-inflammatory activity, makes this worth pursuing in more advanced preclinical models before any clinical claims can be made.

Table 2. Summary of key clinical and translational studies on Salvadora persica

Study design	Population and intervention	Key outcome	Ref
RCT, 3 months	High-caries-risk adults, n=32; miswak toothpaste vs fluoride toothpaste	Both reduced S. mutans equally; fluoride released more remineralising ions	[27]
Ex vivo	Demineralised premolars; S. persica extract vs probiotic yogurt	Superior remineralisation with S. persica; enamel Ca/P near normal	[22]
Meta-analysis, 5	Miswak chewing sticks vs	Comparable plaque; superior gingival	[25]

RCTs	standard toothbrush	outcomes with miswak	
Meta-analysis, 10 RCTs	Miswak sticks and adjunctive use vs toothbrush	Miswak alone equivalent; adjunctive use significantly better	[6]
RCT, 3 weeks, n=78	S. persica stick, S. persica toothbrush, standard brush	All arms equivalent; stick best for anterior gingival inflammation	[7]
RCT, 2 weeks, n=60	Miswak vs toothbrush	Plaque controlled; higher gingival scores linked to aggressive technique	[26]
Meta-analysis, 7 RCTs	S. persica toothpaste vs non-herbal toothpaste	Similar anti-plaque and anti-gingivitis performance	[29]
Meta-analysis, 16 RCTs	S. persica mouthwash vs chlorhexidine gluconate	Significant plaque and gingivitis reduction; slightly inferior to chlorhexidine	[8]
Clinical trial, 2 months	40% miswak mouthwash vs 0.12% chlorhexidine	Chlorhexidine superior for plaque; miswak acceptable for long-term use	[32]
Clinical trial, post-periodontal therapy	Smokers and non-smokers; S. persica vs chlorhexidine mouthwash	Chlorhexidine better for Candida carriage; miswak comparable for soft tissue inflammation	[33]
In vivo rat model	Extraction sockets and tongue incisions; 0.05% to 20% miswak extract	20% extract: best mucosal healing and early bone deposition; no toxicity	[30]
In vivo rat ulcer model	Muco-adhesive SPEAF gel on acetic acid tongue ulcers	Faster healing; reduced inflammation; increased collagen and angiogenesis	[23]
In vitro	HNO97 tongue carcinoma cells; BITC and leaf fractions	BITC IC50 approximately 10 μM; IL-8 and TNF-alpha suppression	[10]

RCT: randomised controlled trial; SPEAF: S. persica ethyl acetate fraction; BITC: benzyl isothiocyanate; Ca/P: calcium to phosphorus ratio

5.0 Comparative Efficacy, Commercial Products, and Novel Formulations

5.1 Miswak versus Toothbrush and Chlorhexidine

The comparative evidence for S. persica against conventional oral hygiene tools has been examined in sufficient trials to permit meta-analytic conclusions, though most follow-up periods remain short.

Against standard toothbrushing, the evidence is fairly consistent. Two independent meta-analyses found that miswak chewing sticks produce plaque reductions comparable to a toothbrush, with equal or better gingival outcomes when technique is adequate [25,6]. The adjunctive effect is more striking than the head-to-head comparison. Adding miswak use to regular toothbrushing produced significantly greater plaque and gingivitis reductions than toothbrushing alone, with standardised mean differences in the range of 0.66 to 0.68 [6]. A three-

week RCT with 78 participants confirmed this pattern, finding S. persica toothbrushes and chewing sticks as effective as standard brushes under supervised technique, with the chewing stick producing the greatest anterior gingival improvement [7]. Where outcomes favoured the toothbrush, technique deficiencies in miswak users were the most consistently cited explanation rather than any inherent limitation of the plant [26]. A systematic review of traditional oral hygiene practices reached a broadly similar conclusion, noting that miswak frequently performs comparably to or better than conventional tools in short-term trials across diverse study populations [31].

Against chlorhexidine, the picture is more nuanced. A meta-analysis of sixteen RCTs found S. persica mouthwash produced significant reductions in plaque and gingival inflammation, but performance was generally below chlorhexidine for plaque control, with gingival outcomes more closely matched between the two agents [8]. A blinded RCT comparing 40% miswak mouthwash with 0.12% chlorhexidine over two months found that chlorhexidine produced lower plaque and gingival scores, yet miswak still reduced both measures significantly from baseline and was considered acceptable for sustained use without the staining and mucosal irritation associated with chlorhexidine [32]. In smokers and non-smokers following non-surgical periodontal therapy, chlorhexidine showed greater efficacy in reducing oral Candida carriage, while S. persica mouthwash produced comparable soft tissue anti-inflammatory outcomes [33]. This pattern, where miswak matches chlorhexidine for tissue-level inflammation control but falls slightly short on microbial load reduction, recurs across several trials and suggests the two agents have partially distinct mechanisms of action that could complement each other in combined protocols.

5.2 Commercial Products

Miswak is now available in multiple commercial forms beyond the chewing stick. Toothpaste formulations, standalone mouthwashes, and multi-herbal product lines have each been evaluated. A commercial miswak herbal toothpaste reduced salivary S. mutans counts to the same degree as a fluoride toothpaste over three months in high-caries-risk adults, attributed to the antimicrobial action of BITC and resins rather than mineral ion delivery [27]. A formulation study producing miswak-containing toothpaste, mouthwash, and chewing gum from S. persica combined with Moringa oleifera found significant reductions in total oral bacterial counts across all product types, with all formulations meeting stability and quality standards through shelf-life testing [34]. Active component preservation during manufacturing emerged as a practical concern in this area. One trial found no clear benefit from a miswak toothpaste, and the authors attributed this to loss of volatile bioactives during processing [18]. This points to a formulation challenge that commercial development needs to address specifically.

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5.3 Nanotechnology Applications

Green synthesis of silver nanoparticles using S. persica root extract has produced particles with minimum inhibitory concentrations as low as 0.19 to 0.39 μg/mL against Escherichia coli and Staphylococcus epidermidis, with low cytotoxicity profiles in preliminary testing [35,36]. These values are considerably below the concentrations at which whole extracts show comparable activity, which is the primary argument for nanoparticle-based delivery in oral antimicrobial applications.

Combining S. persica extract with chitosan nanoparticles produced a mouthrinse formulation with synergistic activity against Gram-positive bacteria, Gram-negative bacteria, and Candida species [37]. Scanning electron microscopy confirmed extensive cell lysis in organisms exposed to the combined preparation that was not seen with either component alone, supporting a mechanistic rationale for this pairing beyond simple additive effects [37].

For solid dental materials, nanoparticles of S. persica extract incorporated into a flowable dental composite at up to 10% by weight produced dose-dependent antibacterial activity against S. mutans, S. pneumoniae, and Haemophilus influenzae without reducing bending properties, and increased compressive strength compared to the unmodified material [38]. Wear resistance also improved when resin content was maintained. These mechanical property outcomes matter clinically because antimicrobial additives in dental resins frequently compromise material performance, and the S. persica nanoparticle data suggest this trade-off may be avoidable at concentrations that retain meaningful antibacterial activity [38].

The trajectory here is from extract to nanoparticle to material-integrated antimicrobial, each step increasing both potency and application specificity. Whether these laboratory gains translate to clinical performance in restorations or irrigants remains to be tested in controlled trials.

6.0 Safety, Toxicology, and Special Populations

6.1 In Vitro and In Vivo Safety Profile and Reported Adverse Effects

Animal data on S. persica extracts are broadly reassuring. In a rodent model, oral administration of aqueous S. persica extract over ten days produced hepatic and renal biochemical and histological findings within normal limits, with no organ toxicity or increased apoptosis detected [24]. In a separate mouse study, pretreatment with aqueous S. persica extract before paracetamol overdose attenuated hepatotoxicity, nephrotoxicity, and haematological disturbance, normalising enzyme levels and largely reversing necrotic changes on histology [39]. A review of S. persica's pharmacology and clinical applications describes aqueous extracts as well-tolerated in animal toxicity testing at tested doses [5]. In vitro, a flavonoid-rich fraction from miswak demonstrated a cytotoxicity concentration of approximately 24.5 μg/mL against cultured cells, indicating that

meaningful cytotoxicity only appears at concentrations substantially above what oral use would deliver through brushing or rinsing [40].

Systemic allergic reactions are rare but documented. A ten-year-old boy with pre-existing atopy developed anaphylaxis on two separate occasions immediately following his first and second miswak use, with facial urticaria, angioedema, throat tightness, and respiratory symptoms each time [41]. Prick-to-prick testing with fresh miswak was positive in this patient, while the same test in thirty adult volunteers, including habitual miswak users returned negative results, pointing to an individual IgE-mediated response rather than a general irritant effect [41]. Prior literature had documented only two cases of cutaneous allergic reactions across a very large global user population, which places the frequency of serious hypersensitivity in perspective without dismissing it as a clinical concern [5,41].

Gingival recession and cervical tooth wear attributed to miswak use are also documented, but these outcomes appear consistently linked to aggressive or incorrect technique rather than any direct toxic property of the plant [9].

6.2 Use in Children and Pregnant Women

The anaphylaxis case confirms that children do use miswak, and that atopic children carry a non-trivial risk of severe allergic response on first exposure [41]. Beyond that single case report, controlled paediatric safety or dosing data are absent from the available literature. No trial in the current evidence set evaluated S. persica use in pregnant or lactating women, and reproductive or developmental toxicity data at oral-care-relevant exposures have not been reported [5]. Available rodent safety studies used adult male animals exclusively, which limits any extrapolation to foetal or early-life exposure [24,39,42]. Placental transfer, teratogenicity, and neonatal outcomes have not been examined.

Topical use in healthy adults appears safe based on current data. For children, particularly those with atopic histories, and for pregnant women, the absence of targeted safety studies means that use should be considered on an individual risk-benefit basis until appropriate studies are conducted.

7.0 Future Directions and Conclusions

7.1 Standardisation, Long-Term RCTs, and Microbiome-Level Studies

The most persistent limitation across the miswak evidence base is methodological inconsistency. Systematic reviews note that brushing technique, stick preparation, frequency of use, and extract concentration are reported differently across trials, often incompletely, which restricts both cross-study comparability and the reliability of pooled estimates [6,18]. Even well-designed recent RCTs standardised technique only over two to three week periods, leaving questions about

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whether outcomes hold over longer use [7]. Systematic reviews on antibiofilm activity specifically call for trials with longer follow-up, larger sample sizes, improved blinding, and harmonised protocols to clarify how sustained miswak use affects biofilm maturation and whether adherence differs between populations with and without cultural familiarity with the practice [18].

The microbiome dimension is almost entirely unexplored. Most trials measure plaque index and gingival index as proxies for oral health, with salivary S. mutans counts representing the limit of microbiological characterisation in better-designed studies. Subgingival microbiome composition, ecological shifts in the oral bacterial community following sustained miswak use, and potential resistance implications of long-term BITC exposure have not been studied in any trial within the current evidence set [6,18]. This is a meaningful gap given that one of the concerns raised about broad-spectrum chemical antiseptics is precisely their ecological disruption of the oral microbiota [4]. Whether miswak produces a more selective antimicrobial effect that preserves commensal species warrants direct investigation using 16S rRNA sequencing or metagenomic approaches. Mechanistic work examining intrapocket application and cellular-level responses in periodontal tissue also remains limited [20,44].

Table 3. Research gaps matrix for Salvadora persica in oral therapeutics

Outcome area	Adult studies available	Paediatric data	Long-term data (>3 months)	Pregnant women	Dental materials	Priority level
Plaque and gingivitis control	Multiple RCTs and meta-analyses [6,7,25,26]	None identified	Very limited; most trials 2 to 3 weeks [6,18]	None	Emerging; toothpaste and mouthwash formulations [29,8]	Moderate; long-term RCTs needed
Dental caries prevention	Limited RCT data; mainly antibacterial endpoints [27,18]	One in vitro polyherbal study only [28]	None identified	None	Ex vivo remineralisation only [22]	High; clinical remineralisation trials needed
Halitosis management	No primary clinical trials identified	None	None	None	None	High; targeted VSC outcome trials absent
Oral candidiasis	No clinical trials; in	None	None	None	None	High; no clinical

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	vitro and nanoparticle data only [5,37]					evidence base
Oral wound healing and mucositis	Animal models only [23,30]	None	None	None	None	High; no human clinical trials
Antiproliferative and anticancer activity	In vitro cell line data only [10]	None	None	None	None	Very high; preclinical stage only
Microbiome-level effects	Not characterised in any included trial [6,18]	None	None	None	None	Very high; 16S rRNA and metagenomic studies absent
Safety and adverse effects	Adult data reassuring; technique-related effects documented [5,9,41]	One anaphylaxis case report [41]	None beyond adverse effect surveillance	None	Low cytotoxicity in vitro [40]	High; paediatric and pregnant population data absent
Nanotechnology formulations	In vitro and material testing only [37,38]	None	None	None	Promising mechanical and antimicrobial data [38]	Moderate; clinical validation needed
Sustainability and sourcing	Ecological threat documented [5,13]	Not applicable	Not applicable	Not applicable	Not applicable	Moderate; policy and cultivation frameworks needed

VSC: volatile sulphur compounds; RCT: randomised controlled trial

7.2 Sustainability, Ethical Sourcing, and Global Integration

Miswak's place in the broader conversation about sustainable oral care is increasingly documented. A 2024 study comparing S. persica, bamboo, and nylon toothbrushes found clinical non-inferiority for plaque removal and gingival bleeding between biodegradable brush types and standard nylon, with lower bristle contamination in the S. persica brush [43]. This performance

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equivalence alongside biodegradability places miswak-based products within the growing framework of eco-conscious dentistry, which seeks to reduce plastic waste and dependency on chemically complex formulations [45,46].

One Health and planetary health frameworks now formally incorporate oral health, arguing that sustainable oral care should reduce environmental burden, address inequities in access, and support people-centred systems [45,46]. Miswak fits within this framing in several respects: it is biodegradable, low-cost, locally available in regions where the tree grows, and culturally integrated in communities that face the greatest barriers to conventional oral care access.

The supply side carries its own responsibilities. Ethnopharmacological surveys document that S. persica is under threat from overexploitation and habitat loss in parts of the Arabian Peninsula [5,13]. Scaling commercial use of miswak extracts and nanoparticle derivatives without addressing cultivation and conservation creates a tension between therapeutic opportunity and ecological harm. Integrating S. persica into modern oral health systems requires frameworks for sustainable harvesting, community benefit sharing, and protection of traditional knowledge that go beyond simple ingredient sourcing [13,45].

7.3 Conclusions

Salvadora persica has moved well beyond its traditional identity as a cultural practice. There is now a body of clinical trial data, systematic reviews, mechanistic studies, and formulation research that together support its use as an effective agent for plaque control and gingival health in adults. Its primary antimicrobial mechanism through benzyl isothiocyanate is well characterised, its anti-inflammatory effects are supported by both animal models and in vitro evidence, and its remineralising potential, while not yet equivalent to fluoride in ion delivery, shows genuine promise in ex vivo testing.

The evidence is clearest for periodontal applications. Miswak in stick, toothpaste, and mouthwash form controls plaque and reduces gingival inflammation to a degree comparable with conventional tools and adds measurable benefit when used alongside standard toothbrushing. Its performance relative to chlorhexidine is somewhat lower for plaque control but comparable for soft tissue anti-inflammatory outcomes, and it avoids the adverse effect profile that limits long-term chlorhexidine use. Wound healing and antiproliferative data are promising but remain at the preclinical stage and need controlled clinical investigation before any therapeutic claims in those areas can be made.

What the evidence does not yet provide is sufficient data on long-term safety, standardised dosing, paediatric use, microbiome-level effects, or outcomes beyond three months. These are not minor gaps. They determine whether S. persica can be formally integrated into clinical practice guidelines rather than simply acknowledged as a comparably effective traditional option. Addressing them requires a shift toward adequately powered, long-term trials with harmonised

protocols, microbiome endpoints, and populations that include children and pregnant women. The ecological and ethical dimensions of scaling miswak use globally also need to be built into that research agenda from the outset, not treated as secondary considerations.

References

1. Bernabé E, Marcenes W, Abdulkader R, et al. Trends in the global, regional, and national burden of oral conditions from 1990 to 2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2025. doi:10.1016/s0140-6736(24)02811-3
2. Wu J, Chen J, Lv C, Zhou L. Global, regional, and national levels and trends in burden of dental caries and periodontal disease from 1990 to 2035: result from the Global Burden of Disease Study 2021. BMC Oral Health. 2025;25. doi:10.1186/s12903-025-06108-w
3. Deus FP, Ouanounou A. Chlorhexidine in dentistry: pharmacology, uses, and adverse effects. Int Dent J. 2022;72:269–277. doi:10.1016/j.identj.2022.01.005
4. Takenaka S, Sotozono M, Ohkura N, Noiri Y. Evidence on the use of mouthwash for the control of supragingival biofilm and its potential adverse effects. Antibiotics. 2022;11. doi:10.3390/antibiotics11060727
5. Farag M, Abdel-Mageed WM, Gamal AEA, Basudan O. Salvadora persica L.: toothbrush tree with health benefits and industrial applications — an updated evidence-based review. Saudi Pharm J. 2021;29:751–763. doi:10.1016/j.jsps.2021.05.007
6. Ramli H, Aripin KNN, Said SM, Hanafiah R, Dom TNM. The effectiveness of miswak (Salvadora persica L. and Azadirachta indica A.Juss.) practices in reducing plaque and gingivitis among adults: a systematic review and meta-analysis. J Ethnopharmacol. 2022. doi:10.1016/j.jep.2022.115598
7. Azizan NF, Mohd N, Azis NMN, Baharin B. Effectiveness of Salvadora persica toothbrush and Salvadora persica chewing stick in plaque and gingivitis control: a randomized control trial. BMC Complement Med Ther. 2023;23. doi:10.1186/s12906-023-04295-z
8. Adam FA, Mohd N, Rani H, Yusof MMYP, Baharin B. A systematic review and meta-analysis on the comparative effectiveness of Salvadora persica extract mouthwash with chlorhexidine gluconate in periodontal health. J Ethnopharmacol. 2022. doi:10.1016/j.jep.2022.115863
9. Ramli H, Mohd-Dom T, Mohd-Said S. Clinical benefits and adverse effects of siwak (S. persica) use on periodontal health: a scoping review of literature. BMC Oral Health. 2021;21. doi:10.1186/s12903-021-01950-0
10. Kobetitsch S, Gierlikowska B, Kunert O, et al. Salvadora persica leaves: phytochemical profile and in vitro-inhibitory activity on inflammatory mediators implicated in periodontal disease. Pharm Biol. 2024;62:563–576. doi:10.1080/13880209.2024.2374801

11. El-Sherbiny G, Gazelly AM, Sharaf M, et al. Exploitation of the antibacterial, antibiofilm and antioxidant activities of Salvadora persica (miswak) extract. J Bioresour Bioprod. 2022. doi:10.1016/j.jobab.2022.11.006
12. Ibrahim I, Moussa A, Chen Z, Zhang J, Cao W, Yu C. Bioactive phenolic components and antioxidant activities of water-based extracts and flavonoid-rich fractions from Salvadora persica L. leaves. Nat Prod Res. 2021;36:2591–2594. doi:10.1080/14786419.2021.1908281
13. Almasri RS, Bedir AS, Raish SAM. Comprehensive ethnopharmacological analysis of medicinal plants in the UAE: Lawsonia inermis, Nigella sativa, Ziziphus spina-christi, Allium cepa, Allium sativum, Cymbopogon schoenanthus, Matricaria aurea, Phoenix dactylifera, Portulaca oleracea, Reichardia tingitana, Salvadora persica, Solanum lycopersicum. Nutrients. 2025;17. doi:10.3390/nu17030411
14. Khanam A, Ahmad A, Iftikhar N, et al. Variation in phenolic profile, antioxidant, and anti-inflammatory activities of Salvadora oleoides Decene. and Salvadora persica L. fruits and aerial part extracts. Life. 2022;12. doi:10.3390/life12091446
15. Abdel-Razakh HH, Bakari G, Park J, Pan C, Hoza A. Phenolic contents and antioxidant properties of Bauhinia rufescens, Ocimum basilicum and Salvadora persica, used as medicinal plants in Chad. Molecules. 2024;29. doi:10.3390/molecules29194684
16. Umbreen S, Mukhtar N, Harun N, Ali S. Effect of environmental drivers on functional traits of Salvadora population in the semi-arid regions: a case study from Division Sahiwal Pakistan. Ecol Evol. 2025;15. doi:10.1002/ece3.71938
17. Mujeeb A, Abideen Z, Aziz I, et al. Phytoremediation of potentially toxic elements from contaminated saline soils using Salvadora persica L.: seasonal evaluation. Plants. 2023;12. doi:10.3390/plants12030598
18. Vejendla I, Krithikadatta J, Vinothkumar TS, et al. Antibiofilm properties of miswak (Salvadora persica) compared to conventional oral health measures: a systematic review. Scientifica. 2025;2025. doi:10.1155/sci5/9344221
19. Azizan NF, Mohd N, Azis NMN, Baharin B. Knowledge, awareness, and practice towards the use of Salvadora persica L. (miswak) chewing stick: a scoping review. Healthcare. 2025;13. doi:10.3390/healthcare13212747
20. Mekhemar M, Geib M, Hassan Y, Dörfer C. Salvadora persica: nature's gift for periodontal health. Antioxidants. 2021;10. doi:10.3390/antiox10050712
21. Almobarak A, Alqedairi A, Binrayes A, Lambarte R, Niazy AA, Aljarbou FA. Benzyl isothiocyanate exhibits antibacterial and antibiofilm activity against Fusobacterium nucleatum while preserving viability of human bone marrow mesenchymal stem cells: an in vitro study. Front Cell Infect Microbiol. 2025;15. doi:10.3389/fcimb.2025.1683203
22. Bakr N, Mohamed A, Salem G. Comparative evaluation of the remineralizing potential of Salvadora persica and probiotic yogurt on incipient enamel lesions: an ex-vivo study. Dent Med Probl. 2024. doi:10.17219/dmp/158561

23. Ayoub N, Badr N, Al-Ghamdi S, et al. HPLC/MSn profiling and healing activity of a muco-adhesive formula of Salvadora persica against acetic acid-induced oral ulcer in rats. Nutrients. 2021;14. doi:10.3390/nu14010028
24. Bokhary T, Refaat B, Bakr EH, et al. Salvadora persica extract attenuates cyclophosphamide-induced hepatorenal damage by modulating oxidative stress, inflammation and apoptosis in rats. J Integr Med. 2022. doi:10.1016/j.joim.2022.05.001
25. Adam FA, Mohd N, Rani H, Baharin B, Yusof MMYP. Salvadora persica L. chewing sticks and standard toothbrush as anti-plaque and anti-gingivitis tool: a systematic review and meta-analysis. J Ethnopharmacol. 2021. doi:10.1016/j.jep.2021.113882
26. Abdellatif HM, Hebbal M, Alsagob EI, et al. Comparative effectiveness of miswak and toothbrushing on dental plaque and gingivitis: a randomized controlled trial. Healthcare. 2024;12. doi:10.3390/healthcare12212150
27. Shaalan O, El-Rashidy AA. Antibacterial effect of miswak herbal toothpaste compared to fluoride toothpaste in high caries risk patients: randomized clinical trial. J Clin Exp Dent. 2023;15:e526–e534. doi:10.4317/jced.60332
28. Kohli N, Hugar S, Hallikerimath S, Gokhale NS, Kadam KS, Soneta SP. Comparative evaluation of antibacterial efficacy and remineralization potential of acidulated phosphate fluoride gel with herbal dental gel containing Zingiber officinale, Salvadora persica, and Cinnamomum zeylanicum: an in vitro study. Int J Clin Pediatr Dent. 2024;17:307–315. doi:10.5005/jp-journals-10005-2796
29. Adam FA, Mohd N, Rani H, Yusof MM, Baharin B. Salvadora persica L.: an effective anti-plaque and anti-gingivitis toothpaste — a systematic review and meta-analysis of randomized control clinical trials. J Herb Med. 2023. doi:10.1016/j.hermed.2023.100677
30. Harun NA, Ramli N, Azli ARK, Hassan H, Adam KBC, Halil MHM. The effect of Salvadora persica ethanolic extract on oral tissue healing in rats: an in vivo study. Saudi Dent J. 2023;35:663–667. doi:10.1016/j.sdentj.2023.05.019
31. Shahzad M, Ahmad HA, Ambadi S, Peterson SR, Yang I. Traditional oral hygiene practices and their effectiveness: a systematic review of the evidence. Oral Health Prev Dent. 2026;24:107–118. doi:10.3290/j.ohpd.c_2475
32. Al-Mahmood S, Sabea D. Comparative evaluation of the effectiveness of 40% miswak mouthwash and 0.12% chlorhexidine mouthwash in treating gingivitis: a blinded, randomised clinical trial. Oral Health Prev Dent. 2021;19. doi:10.3290/j.ohpd.b1179501
33. Basudan A, Al-Zawawi AS, Divakar D, Shaheen M, Aldulaijan H. Efficacy of 0.12% chlorhexidine and Salvadora persica-based mouthwash in reducing oral Candida carriage and periodontal inflammation in cigarette smokers and non-smokers after non-surgical periodontal therapy. Oral Health Prev Dent. 2023;21. doi:10.3290/j.ohpd.b4169713
34. Barahuie F, Dianat T, Nejad GN, Shahbakhsh M, Tamandani DKK. Evaluation of chemical, biochemical and anti-microbial effects of Salvadora persica and Moringa

oleifera extract to produce organic disinfectant products. Arch Razi Inst. 2023;78(4):1379–1386. doi:10.32592/ari.2023.78.4.1379

35. Arshad H, Sami M, Sadaf S, Hassan U. Salvadora persica mediated synthesis of silver nanoparticles and their antimicrobial efficacy. Sci Rep. 2021;11. doi:10.1038/s41598-021-85584-w
36. Khojasteh-Taheri R, Ghasemi A, Meshkat Z, Sabouri Z, Mohtashami M, Darroudi M. Green synthesis of silver nanoparticles using Salvadora persica and Caccinia macranthera extracts: cytotoxicity analysis and antimicrobial activity against antibiotic-resistant bacteria. Appl Biochem Biotechnol. 2023. doi:10.1007/s12010-023-04407-y
37. Balto H, Bekhit M, Auda S, et al. Synergistic effect of Salvadora persica and chitosan nanoparticles against oropharyngeal microorganisms. Sci Rep. 2024;14. doi:10.1038/s41598-024-63636-1
38. Chaaben R, Mnif B, Elleuch K. Salvadora persica nanoparticles effect on the specific properties of a bio-composite dental material. J Thermoplast Compos Mater. 2025;38:3456–3470. doi:10.1177/08927057251314408
39. Alaraj M, Acar T, Kosińska I, et al. Pretreatment with Salvadora persica L. (miswak) aqueous extract alleviates paracetamol-induced hepatotoxicity, nephrotoxicity, and hematological toxicity in male mice. Vet World. 2021;14:589–594. doi:10.14202/vetworld.2021.589-594
40. Owis A, El-Hawary M, Amir DE, et al. Flavonoids of Salvadora persica L. (meswak) and its liposomal formulation as a potential inhibitor of SARS-CoV-2. RSC Adv. 2021;11:13537–13544. doi:10.1039/d1ra00142f
41. Hussein MO, Alangari AA. First report of anaphylaxis to miswak (Salvadora persica). Pediatr Allergy Immunol. 2024;35. doi:10.1111/pai.14256
42. Youssef B, Ramadan K, ElShebiney SA, Ibrahim EA. Antidepressant-like effects of aqueous extracts of miswak (Salvadora persica) and date palm (Phoenix dactylifera) on depression-like behaviors using CUMS model in male rats. J Food Biochem. 2022. doi:10.1111/jfbc.14164
43. Fageeh HN, Mansoor MA, Fageeh HI, et al. Plaque removal and gingival bleeding using biodegradable toothbrushes: Salvadora persica, bamboo, and nylon — a comparative study. Med Sci Monit. 2024;30. doi:10.12659/msm.944469
44. Abozaid D, Asharf M, Mohamed PA, Mohamed M, Elwakeel E, Azab A. Antimicrobial and physicomechanical performance of Salvadora persica (miswak)-modified glass ionomer cement: a systematic review. Beni-Suef Univ J Basic Appl Sci. 2026;15. doi:10.1186/s43088-026-00742-1
45. Fisher J, Splieth C, Matanhire-Zihanzu CN, Glick M. Advancing the concept of global oral health to strengthen actions for planetary health and One Health. Int J Equity Health. 2024;23. doi:10.1186/s12939-024-02176-6

46. Moussa LG, Sonmez OF, Bedi R. Incorporating oral health into the One Health agenda: contributions and implications. Sci One Health. 2025;4. doi:10.1016/j.soh.2025.100111